

In the Claims

- 1 1. (Currently amended) A method for characterizing a contaminant in a fluid flow system,
2 comprising the steps of:
- 3 (a) injecting a conservative gaseous tracer and an interactive gaseous tracer into the
4 flow system at a first location, wherein the flow system is not completely filled with
5 liquid;
- 6 (b) advecting the tracers along the flow system;
- 7 (c) extracting the tracers at a second location in the flow system;
- 8 (d) measuring the concentration of the extracted tracers over a period of time; and
- 9 (e) characterizing the contaminant from the concentrations of the tracers.
- 1 2. (Original) The method of claim 1 where the concentration is measured as a function of
2 time.
- 1 3. (Original) The method of claim 1 wherein the characterizing includes detecting the
2 presence of a specific contaminant of interest in the fluid flow system.
- 1 4. (Original) The method of claim 1 wherein the characterizing includes locating a specific
2 contaminant of interest in the fluid flow system.
- 1 5. (Original) The method of claim 1 wherein the characterizing includes quantifying the
2 amount of a specific contaminant in the flow system.
- 1 6. (Original) The method of claim 1 wherein the tracers are advected by a fluid that does not

2 interact with the tracers or the contaminant.

1 7. (Original) The method of claim 1 wherein the interactive tracer is a partitioning tracer.

1 8. (Original) The method of claim 1 wherein the interactive tracer is a reactive tracer.

1 9. (Original) The method of claim 1 wherein a plurality of interactive tracers are injected.

1 10. (Currently amended) A method for detecting the presence of a contaminant in a fluid flow
2 system, comprising the steps of:

3 (a) injecting a conservative gaseous tracer and an interactive gaseous tracer into the
4 flow system at a first location, wherein the flow system is not completely filled
5 with liquid;

6 (b) advecting the tracers along the flow system with a fluid that does not interact with
7 the tracers;

8 (c) extracting the tracers at a second location in the flow system;

9 (d) measuring the concentration of the extracted tracers over a period of time; and

10 (e) detecting the presence of the contaminant from a comparison of the measured
11 concentrations.

1 11. (Original) The method of claim 10 where said concentration is measured as a function of
2 time.

1 12. (Original) The method of claim 10 wherein the interactive tracer is a partitioning tracer.

1 13. (Original) The method of claim 10 wherein the interactive tracer is a reactive tracer.

1 14. (Original) The method of claim 10 wherein a plurality of interactive tracers are injected
2 into the fluid flow system.

1 15. (Original) A method for determining the location of a contaminant in a fluid flow system,
2 comprising the steps of:

3 (a) injecting a conservative tracer and a partitioning tracer into the flow system at a
4 first location;

5 (b) advecting the tracers along the flow system at a first velocity to create an advection
6 flow field;

1 (c) extracting the tracers at a second location in the flow system;

2 (d) introducing a perturbation to the advection flow field at a perturbation time by
3 changing and then re-establishing the advection flow at a second velocity, which
4 may be different than the first velocity, creating a unique change in the
5 concentration of the partition tracer;

6 (e) extracting the partitioning tracer as a function of time relative to the perturbation
7 time;

8 (f) measuring the concentration of the partitioning tracer as a function of the time; and

9 (g) determining the location of contamination from the time of arrival of the
10 partitioning tracer relative to the perturbation time and the advection flow velocity.

1 16. (Original) A method for determining the quantity of a contaminant in a fluid flow system,
2 comprising the steps of claim 1, wherein the quantity of extracted tracer is related to the quantity
3 of contaminant.

1 17. (Original) An apparatus for characterizing a contaminant in a fluid flow system,
2 comprising:

- 3 (a) a tracer injection system for injecting known amounts of conservative and
4 interactive tracers into the flow system;
- 5 (b) ~~an~~ a gaseous advection driving system for moving the tracers along the flow system
6 at a known flow rate;
- 7 (c) a tracer extraction system for removing the tracers from the fluid flow system;
- 8 (d) a measurement system for determining the concentration of the tracers extracted
9 from the fluid flow system; and
- 10 (e) a processor for analyzing the concentration measurements.

1 18. (Original) The apparatus of claim 17, wherein the injection system includes a container
2 with a valve holding tracers at pressure, whereby the tracers can be injected into the flow system
3 by depressurizing the container by opening the valve on the container.

1 19. (Original) The apparatus of claim 17, wherein the driving system includes a compressed
2 gas cylinder.

1 20. (Original) The apparatus of claim 17, wherein the measurement system includes a gas
2 chromatograph.

1 21. (New) The method of claim 1 wherein the method of characterizing can be used to
2 characterize said contaminant at more than one location when the tracer concentrations from each
3 location are distinguishable.

1 22. (New) The method of claim 1 wherein the method of characterizing can be used to
2 characterize more than one contaminant in a fluid flow system by using one or more tracers that
3 interact with each contaminant.

1 23. (New) The method of claim 1 wherein the method of characterizing can be used to
2 characterize a plurality of contaminants at a plurality of locations.

1 24. (New) The method of claim 2 wherein said characterizing involves a comparison of the
2 characteristic features of the measured concentrations of the conservative and interactive tracers.

1 25. (New) The method of claim 24 wherein said characteristic features are comprised of the
2 magnitude of the tracer concentrations in certain regions of the concentration curves such as the
3 peak, the leading edge, or the trailing edge of the curves.

1 26. (New) The method of claim 24 where said comparison is accomplished using said tracer
2 concentration curves that represent only a fraction of the total concentration curve that would have
3 been measured if the collection time were extended.

1 27. (New) The method of claim 10 wherein the method of detecting can be used to detect said
2 contaminant at more than one location when the tracer concentrations from each location are
3 distinguishable.

1 28. (New) The method of claim 10 wherein the method of detecting can be used to detect more
2 than one contaminant in a fluid flow system by using one or more tracers that interact with each
3 contaminant.

1 29. (New) The method of claim 10 wherein the method of detecting can be used to detect a

2 plurality of contaminants at a plurality of locations.

1 30. (New) The method of claim 11 wherein said detecting is determined from a comparison of
2 the characteristic features of the measured concentrations of the conservative and interactive
3 tracers.

1 31. (New) The method of claim 30 wherein said characteristic features are comprised of the
2 magnitude of the tracer concentrations in certain regions of the concentration curves such as the
3 peak, the leading edge, or the trailing edge of the curves.

1 32. (New) The method of claim 30 where said comparison is accomplished using said tracer
2 concentration curves that represent only a fraction of the total concentration curve that would have
3 been measured if the collection time were extended.

1 33. (New) The method of claim 15 wherein the injecting and the advecting in steps (a) and (b)
2 of claim 15 are done to inundate the entire fluid flow system with the tracers.

1 34. (New) The method of claim 15 wherein a plurality of partitioning tracers are used.

1 35. (New) The method of claim 15 wherein the presence of the partitioning tracer after the
2 perturbation needed for location of the contaminant is also used to detect the presence of the
3 contaminant.

1 36. (New) The method of claim 15 wherein the time of arrival is determined from the leading
2 edge of the tracer concentration curve.

1 37. (New) The method of claim 15 wherein said second flow velocity is determined from the
2 mean time of arrival of the tracer at said second flow rate.

1 38. (New) The method of claim 15 wherein the location of the contamination is further
2 comprised of the steps of (a) extracting the partitioning tracer at said second location at said first
3 flow rate and measuring the concentration of the partitioning tracer over a period of time and (b)
4 determining the location of the contaminant from (1) the times of arrival of the partitioning tracer
5 relative to the start time of the second advection flow after the perturbation and to the start time of
6 the first advection flow and (2) the flow rates of the second advection flow and the flow rate of the
7 first advection flow.

1 39. (New) The method of claim 15 wherein the method of location can be used to locate said
2 contaminant at more than one location when the tracer concentrations from each location are
3 distinguishable.

1 40. (New) The method of claim 15 wherein the method of location can be used to locate more
2 than one contaminant in a fluid flow system by using one or more tracers that interact with each
3 contaminant.

1 41. (New) The method of claim 15 wherein the method of location can be used to locate a
2 plurality of contaminants at a plurality of locations.

- 1 42. (New) The method of claim 16 wherein the quantity of a contaminant in a fluid flow
2 system is determined from the time of arrival of the conservative and the interactive tracer.
- 1 43. (New) The method of claim 16 wherein the interactive tracer is a partitioning tracer.
- 1 44. (New) The method of claim 16 wherein the interactive tracer is a reactive tracer.
- 1 45. (New) The method of claim 16 wherein a plurality of interactive tracers are injected.
- 1 46. (New) The method of claim 16 in which the partitioning tracers have sufficient time to
2 fully dissolve and interact with the contaminants in the fluid flow system.
- 1 47. (New) The method of claim 16 wherein said quantification is determined from a
2 comparison of the characteristic features of the measured concentrations of the conservative and
3 interactive tracers.
- 1 48. (New) The method of claim 33 wherein the partitioning tracer that is injected into the fluid
2 flow system is allowed sufficient time for the tracer to interact with the contaminant before the
3 tracer is advected.
- 1 49. The method of claim 33, wherein only the section of the fluid flow system that is
2 contaminated need be inundated with tracer.

1 50. (New) The method of claim 33 wherein the presence of the partitioning tracer after the
2 perturbation needed for location of the contaminant is also used to detect the presence of the
3 contaminant.

1 51. (New) The method of claim 33 wherein the time of arrival is determined from the leading
2 edge of the tracer concentration curve.

1 52. (New) The method of claim 33 wherein said second flow velocity is determined from the
2 mean time of arrival of the tracer at said second flow rate.

1 53. (New) The method of claim 33 wherein the method of location can be used to locate said
2 contaminant at more than one location when the tracer concentrations from each location are
3 distinguishable.

1 54. (New) The method of claim 33 wherein the method of location can be used to locate more
2 than one contaminant in a fluid flow system by using one or more tracers that interact with each
3 contaminant.

1 55. (New) The method of claim 33 wherein the method of location can be used to locate a
2 plurality of contaminants at a plurality of locations.

1 56. (New) The method of claim 35 wherein the method of detection can be used to detect said
2 contaminant at more than one location when the tracer concentrations from each location are
3 distinguishable.

1 57. (New) The method of claim 35 wherein the method of detection can be used to detect more
2 than one contaminant in a fluid flow system by using one or more tracers that interact with each
3 contaminant.

1 58. (New) The method of claim 35 wherein the method of detection can be used to detect a
2 plurality of contaminants at a plurality of locations.

1 59. (New) The method of claim 35 wherein said detecting is determined from a comparison of
2 the characteristic features of the measured concentrations of the conservative and interactive
3 tracers.

1 60. (New) The method of claim 50 wherein the method of detection can be used to detect said
2 contaminant at more than one location when the tracer concentrations from each location are
3 distinguishable.

1 61. (New) The method of claim 50 wherein the method of detection can be used to detect more
2 than one contaminant in a fluid flow system by using one or more tracers that interact with each
3 contaminant.

1 62. (New) The method of claim 50 wherein the method of detection can be used to detect a
2 plurality of contaminants at a plurality of locations.

1 63. (New) The method of claim 50 wherein said detecting is determined from a comparison of

2 the characteristic features of the measured concentrations of the conservative and interactive
3 tracers.

1 64. (New) The method of claim 37 wherein said mean time of arrival is determined from the
2 centroid of the tracer concentration curve.

1 65. (New) The method of claim 38 wherein the location is determined from the product of the
2 ratio of the time of arrival of the partitioning tracer at the second flow rate relative to the first flow
3 rate, the ratio of the flow rate of the partitioning tracer at the second flow rate relative to the first
4 flow rate, and the length of the fluid flow system between the injection and extraction points.

1 66. (New) The method of claim 52 wherein said mean time of arrival is determined from the
2 centroid of the tracer concentration curve.

1 67. (New) The method of claim 50 wherein said characteristic features are comprised of the
2 magnitude of the tracer concentrations in certain regions of the concentration curves such as the
3 peak, the leading edge, or the trailing edge of the curves.

1 68. (New) The method of claim 50 where said comparison is accomplished using said tracer
2 concentration curves that represent only a fraction of the total concentration curve that would have
3 been measured if the collection time were extended.

1 69. (New) The method of claim 63 wherein said characteristic features are comprised of the
2 magnitude of the tracer concentrations in certain regions of the concentration curves such as the

3 peak, the leading edge, or the trailing edge of the curves.

1 70. (New) The method of claim 63 where said comparison is accomplished using said tracer
2 concentration curves that represent only a fraction of the total concentration curve that would have
3 been measured if the collection time were extended.

1 71. (New) The method of claim 43 for determining the quantity of a contaminant in a fluid
2 flow system wherein the partitioning coefficient of the partitioning tracer is known.

1 72. (New) The method of claim 71 in which the quantity of the contaminant is determined
2 from the ratio of the mean time of arrival of the partitioning and conservative tracers.

1 73. (New) The method of claim 71 in which said mean arrival times of the partitioning and the
2 conservative tracers are be determined from the centroid of said tracer concentration curves.

1 74. (New) The method of claim 72 where said comparison is accomplished using said tracer
2 concentration curves that represent only a fraction of the total concentration curve that would have
3 been measured if the collection time were extended.

1 75. (New) The method of claim 74 where said comparison is accomplished with said fractional
2 concentration curve by mathematically extrapolating the curve.

1 76. (New) The method of claim 74 further comprising the step of applying a factor accounting
2 for the geometry of the fluid flow system.

- 1 77. (New) The method of claim 47 wherein said characteristic features are comprised of the
- 2 magnitude of the tracer concentrations in certain regions of the concentration curves such as the
- 3 peak, the leading edge, or the trailing edge of the curves.